ANALYZING STOPPING BEHAVIOR AT RURAL INTERSECTIONS USING SHRP 2 NATURALISTIC DRIVING DATA

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ABSTRACT

Rural intersections account for 30% of crashes in rural areas and 6% of all fatal crashes, representing a significant but poorly understood safety problem. Transportation agencies have traditionally implemented countermeasures to address rural intersection crashes by increasing intersection conspicuity. Frequently they do not understand how these countermeasures, and driver, environmental and other roadway factors interact to affect stopping behavior. The Second Strategic Highway Safety Program (SHRP 2) conducted a large-scale naturalistic driving study (NDS) using instrumented vehicles which provides a significant amount of on-road driving data for a range of drivers. This study utilized the NDS data to observe driver stopping behavior at rural intersections using video and vehicle kinematics data.

A model of driver braking behavior was developed using a small dataset of vehicle activity traces for several rural stop-controlled intersections. The model was developed using the point at which a driver reacts to the upcoming intersection by intitating braking as its dependent variable with drivers age , type and direction of turning movement, as well as countermeasure presence as independent variables. Results of the study can lead to better design, more informed selection of traffic control and countermeasures, and targeted information to inform policy decisions.

1. INTRODUCTION

Rural intersections account for 30% of crashes in rural areas and 6% of all fatal crashes, representing a significant but poorly understood safety problem. Transportation agencies have traditionally implemented countermeasures to address rural intersection crashes by increasing intersection conspicuity. Frequently they do not understand how these countermeasures, and driver, environmental and other roadway factors interact to affect stopping behavior.

Most studies to assess intersection braking behavior have used simulators (Montella et al., 2011), closed course studies (Muttart et al, 2011), or controlled instrumented vehicles with test drivers (Bao and Boyle, 2008). The drawback to these types of studies is that they are limited in the number of drivers that can be included and it is difficult to test real-world conditions. Some studies have collected driver stopping behavior by reducing video data collected at actual intersections which requires collecting data for significant distances upstream using multiple video data collection arrays and driver characteristics cannot be obtained. With each of the above types of data collection, it is difficult to represent a wide array of different intersections. This project uses the SHRP 2 Naturalistic Driving Study data (NDS) to help address the drawbacks of these previous studies.

The objective of this study was to develop a model of driver braking behavior at rural intersections incorportating driver, environmental, and roadway charactersitic including different countermeasures commonly used at rural intersections to increase thier conspicuity. The results of this research effort will develop guidance that will allow transportation agencies to more efficiently apply countermeasures at rural intersections.

2. DATA REDUCTION

The SHRP2 NDS data and Roadway Information Database (RID) were the main data source for this project. The NDS data used in this study included time series data which included data sampled at 0.1 second intervals and forward video data for each trace, or one trip through one intersection. Time series data for 392 traces through 58 intersections were reduced down to 129 traces through 38 intersections which were used in the analysis. The 263 unused traces were removed due to brake pedal data not being present, forward video not being available, intersection approach being downhill or having a railroad crossing, or the vehicle was following another vehicle. The following drivers were removed so only free flow vehicles remained as they are not influenced by the lead vehicle. The traces where the approach was downhill or had a railroad crossing were removed as the reaction distance appeared to be more in response to these and not the upcoming intersection.

Using the time series data, the braking point where the driver reacted to the intersection was extracted. This was done by first finding the location of the intersection within the time series data. This was done using the GPS coordinates in the time series data along with the GPS coordinates of the intersections provided in the rid and finding the closest point to each intersection. The coordinates of the intersection from the RID are to the center of the intersection, and not to the stop bar. This was used as the data were readily available and consistent. Once the intersection was found within the time series data, speed and time were used to calculate the distance from the intersection. Then the point where the driver initiated braking upstream of the intersection was found and determined to be the reaction point.

Additional data collected include roadway data such as number of lanes, presence of turn lanes, type of intersection, turning movement, if they were yielding (major to minor road) or stopping (minor to major road), and if the approach to the intersection was within a curve. Countermeasure data such as the presence of overhead flashing beacons, presence of on pavement signing, advanced intersection and stop sign signing, and the presence of double stop signs were also extracted. Environmental data including time of day and whether the roadway was wet or snowy were extracted from the forward video of each trip. Additional driver data such as their age and gender were also included.

3. ANALYSIS AND RESULTS

A Linear mixed effects model was used in our analysis. The mixed effects model lets us take into account the multiple samples from some intersections. The model was developed using the lmer() function in the lme4 package in R with the distance upstream (m) at which the driver began braking in response to the intersection as the depend variable. Variables were included if they were significant at a 90% confidence level. Models were compared using the Akaike information criterion (AIC) to determine which had a better fit. Once the model was developed it was checked to make sure it met the linear model assumptions. The best fit model can be seen in Table 1. Also included in Table 1 is the percent of samples each of the dummy variables when equal 1(i.e. for stop or yield, % that are yield).

Table 1: Model Results

Variable	Estimate	Std error	P value	% samples
Intercept	133.30	10.04	<0.0001	
Stop or Yield (1=yield, 0=stop)	41.10	10.58	0.0001	50.38%
Overhead flashing beacon present (1=present, 0 =not present)	67.11	22.42	0.0028	11.62%
On pavement signing present (1= present, 0= not present)	46.34	20.84	0.0261	10.08%
Driver's age is under 25(1=under 25, 0=25 or older)	-39.29	21.62	0.0691	7.75%
Drivers turning direction (1=right, 0=left)	-18.66	10.90	0.0869	45.7%

This best fit model included five variables as well as an intercept. The model found that the presence of countermeasures such as overhead flashing beacons and on pavement signing increased the distance at which the driver began reacting to the intersection 67 m and 46 m further upstream, respectively, than those intersections without them. These findings show that the countermeasures appear to be working as intended by alerting the drivers to the intersections sooner and therefore they react earlier. Younger drivers (<25) were found to begin braking approximately 40 m later than those drivers 25 or older. It was also found that those drivers turning from a major road to a minor road (yielding) begin braking about 40 m earlier than those approaching a stop sign. The model also showed that a driver turning right would brake 18 m later than a driver turning left.

4. CONCLUSIONS AND DISCUSSION

A linear mixed effects model was developed which predicts how far upstream of an intersection a driver reacts to the intersection by intiating braking. The model found that countermeasures which are intended to alert drivers to the presence of the intersection such as overhead flashing beacons and on pavement signing increase the distance at which the driver begins braking. This supports the use of the countermeasures as they appear to be working as intended by drawing drivers attention to the intersections causing them to react earlier. Younger drivers were found to be more aggressive than older drivers by braking almost 40 m later than drivers over 25. This finding supports continued education for younger drivers, making sure they pay adequate attention to the roadway. Additonal findings include that drivers turning from the major roadway to the minor roadway begin braking sooner than those turning from the minor roadway to the major roadway. This may be due to the major roadway having a higher speed limit which would necesitate braking earlier. Futures studies could hope address this by incorporating speed limit data or if the driver was speeding within models.

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